COMSOL CONFERENCE 2016 MUNICH

Munich, 2016

Credits

Project RFMEFI60714X0008 “**Development of methods for complex diagnostics of onboard equipment of spacecraft on resistance to arcing**” of the Ministry of Education and Science of Russian Federation

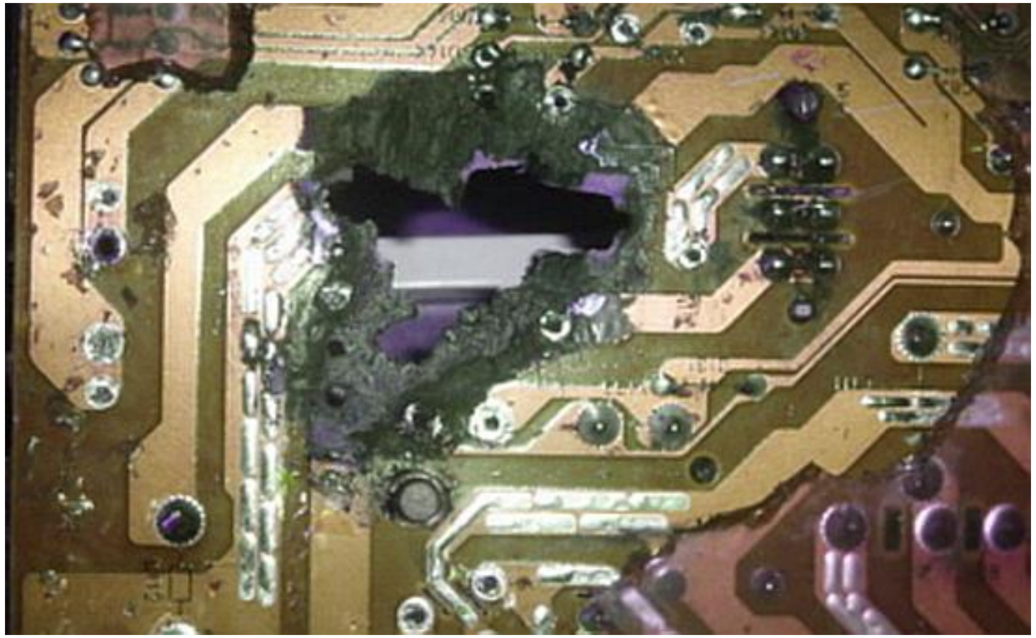
Participants:

- **Institute of High Current Electronics**, Tomsk, Russia
- **Tomsk State University**, Tomsk, Russia
- **Tomsk State University of Control Systems and Radioelectronics**, Tomsk, Russia

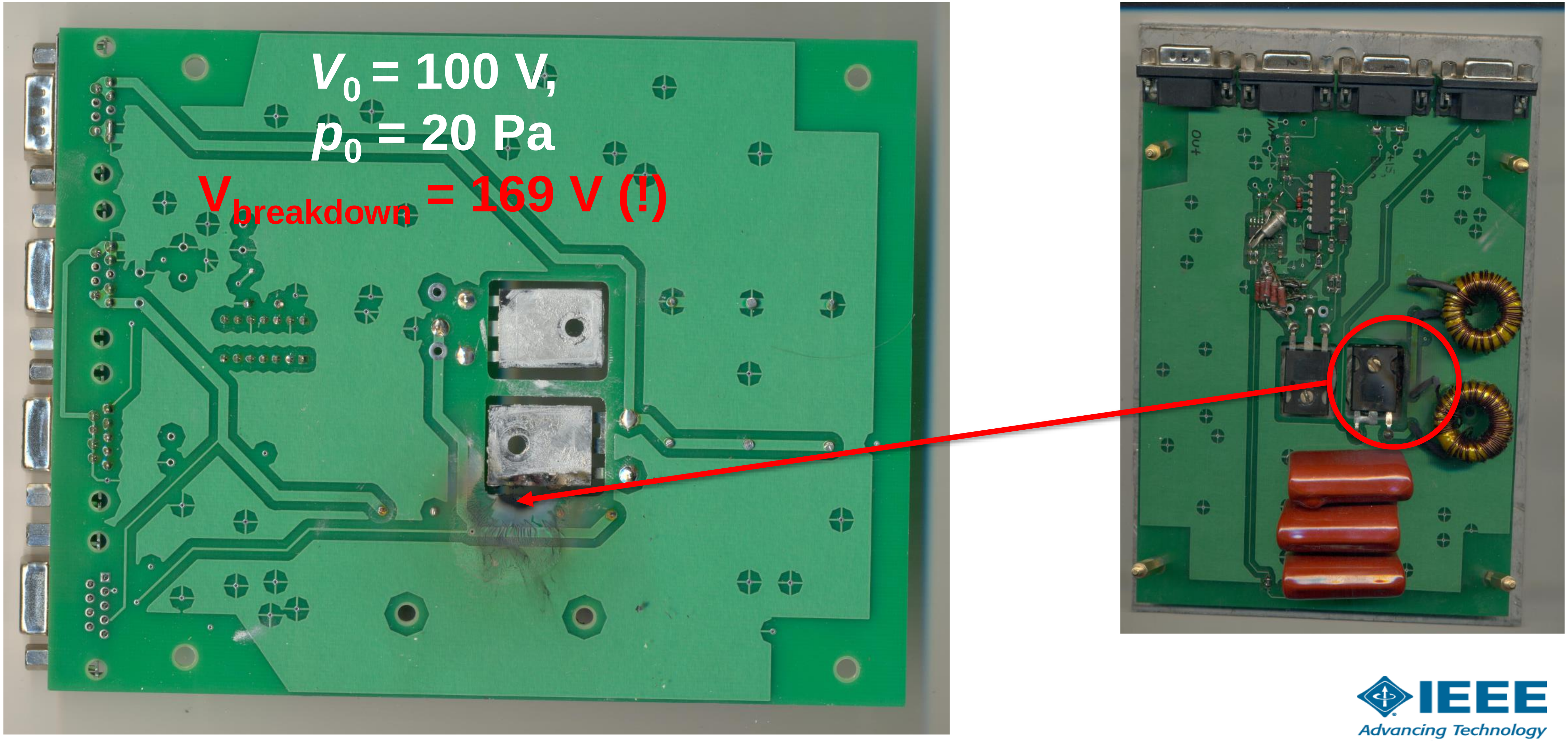
Root problem

Today, in civil spacecraft the electric arcing is one the main factors leading to partial or complete failure of electronic equipment.

This problem escalates with the increase of operating voltages from 27 Volts up to 100 Volts since 2000.

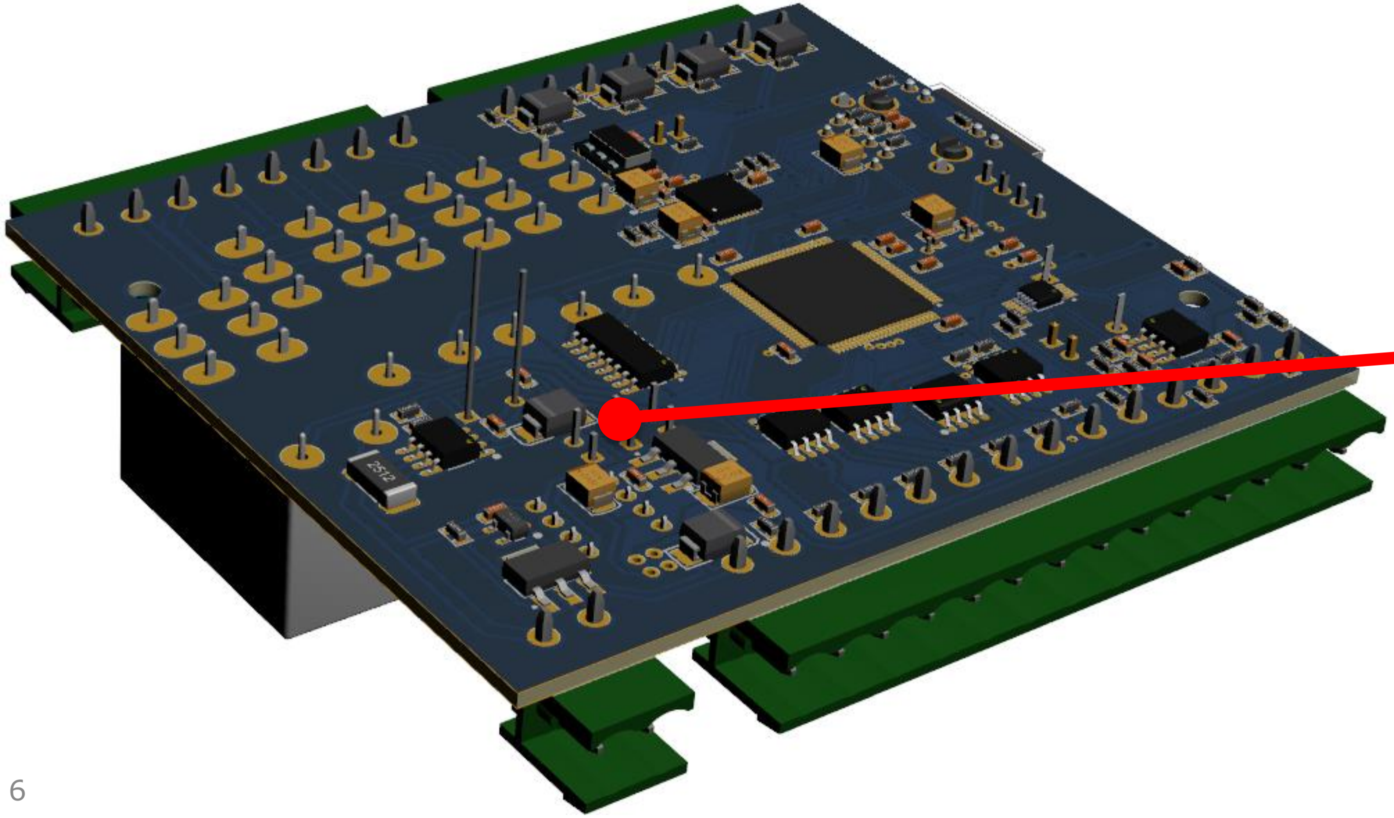


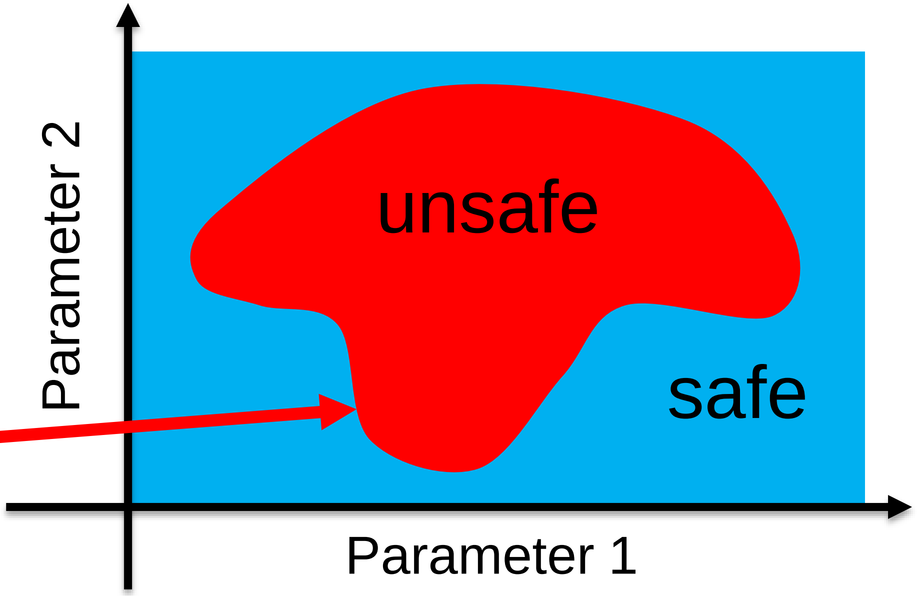
Experimental example of primary arc below Paschen's minimum (in Ar)



What is diagnostics ?

- Search for the region where the self-sustained discharge is most probable;
- Investigate multiple conditions of arcing with respect to variation of main parameters (pressure, electrons emission, etc.)

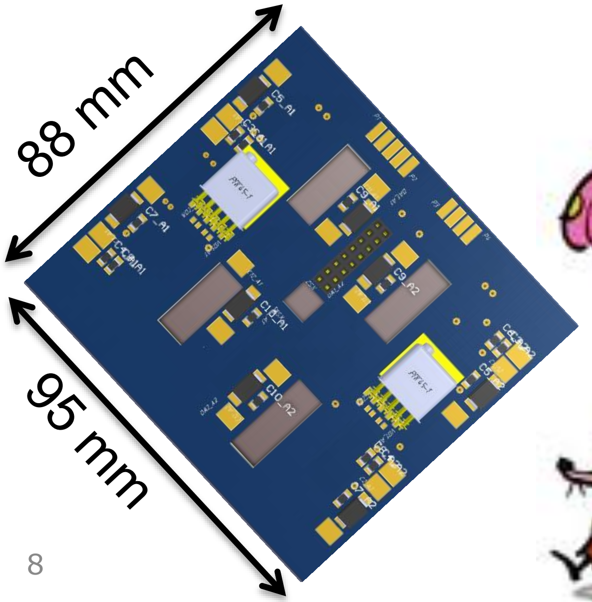


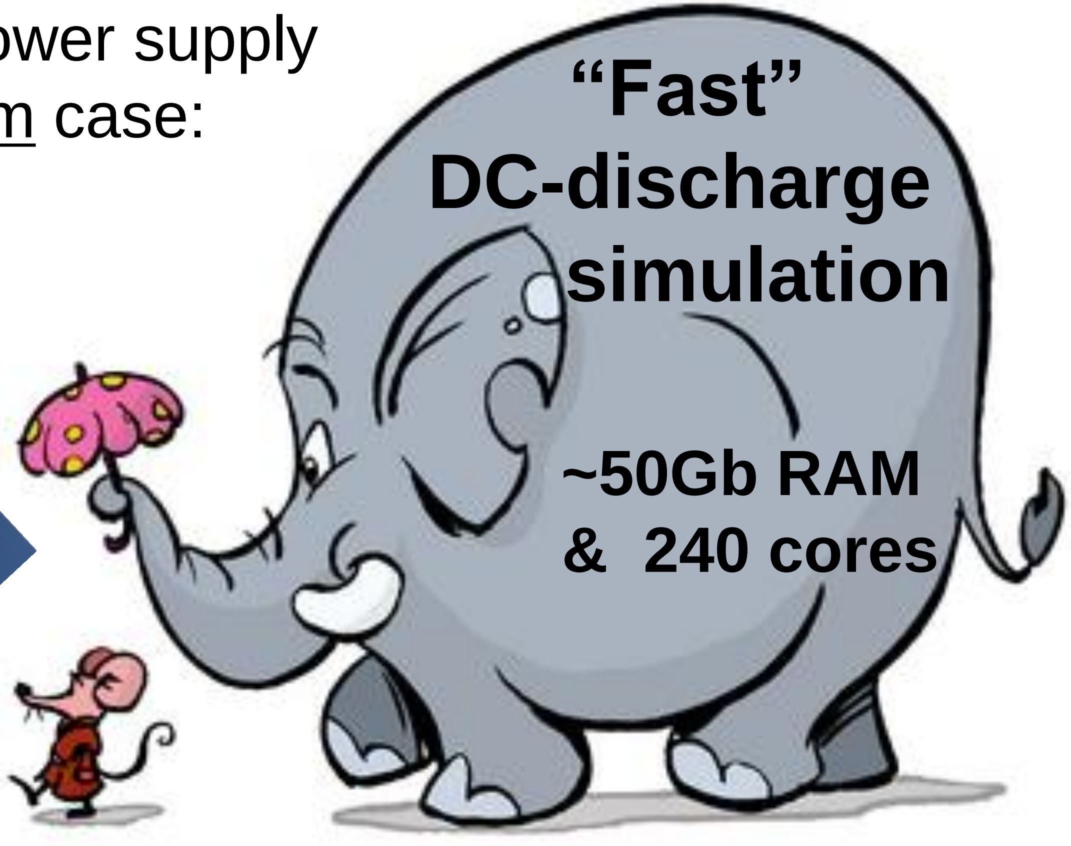


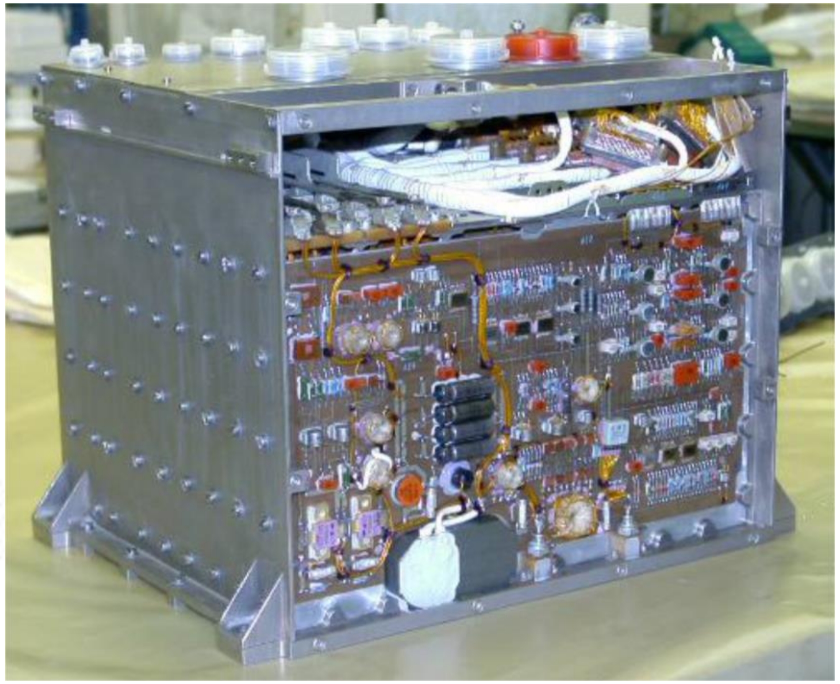
Multiscale problem
(Full-scale DC-discharge simulation)

Device size ~ 500 mm,
Critical region ~ 1-5 mm
Debye length ~ 0.01-0.1 mm

Satellite secondary power supply
in 231x174x30 mm case:







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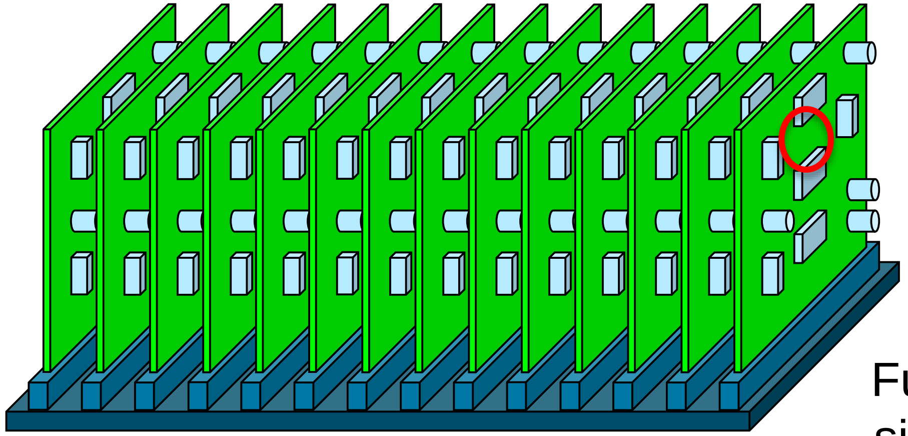
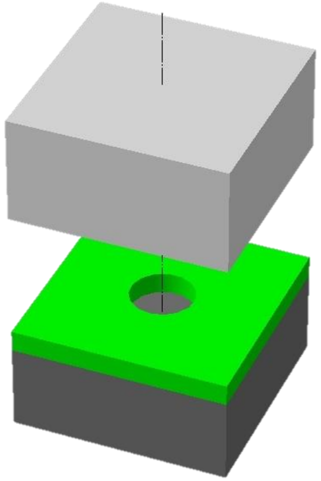
Our approach

1) Electric field-enhancement regions extraction

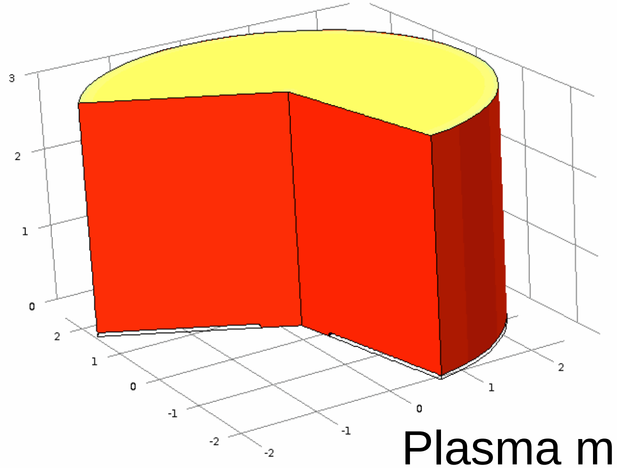


~~Debye length scale~~

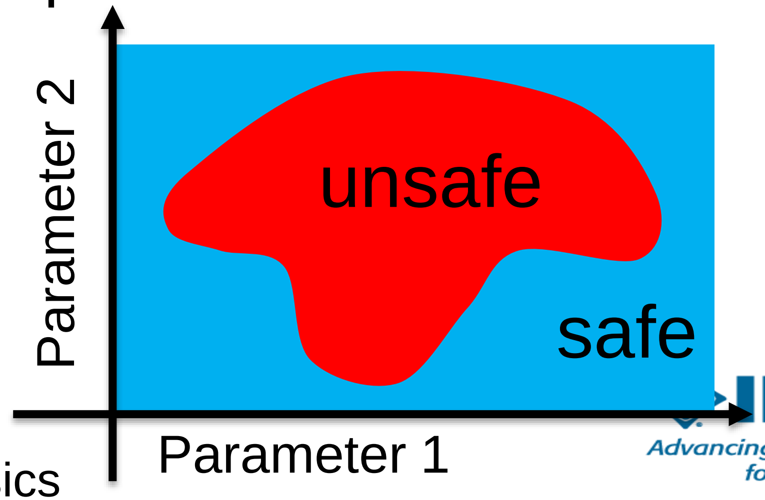


Full-scale SPICE + Electrostatics simulation (AC/DC module of COMSOL Multiphysics)

2) DC-discharge simulation + Parametric sweep option



~~Device scales~~



Plasma module of COMSOL Multiphysics

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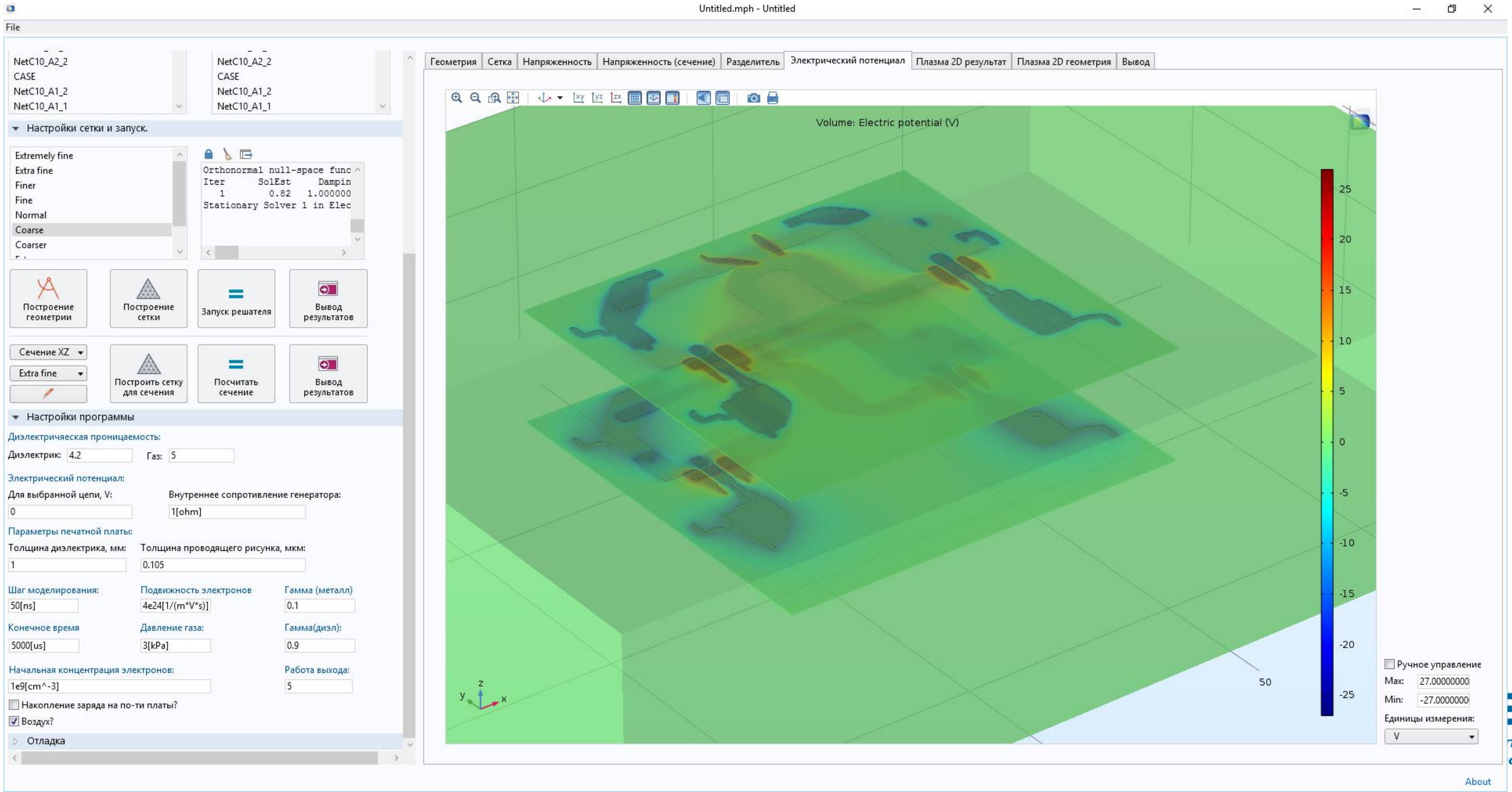
Software interface



Preprocessing module

✓ COMSOL Application Builder

- Complete PCB (ASCII) file format import

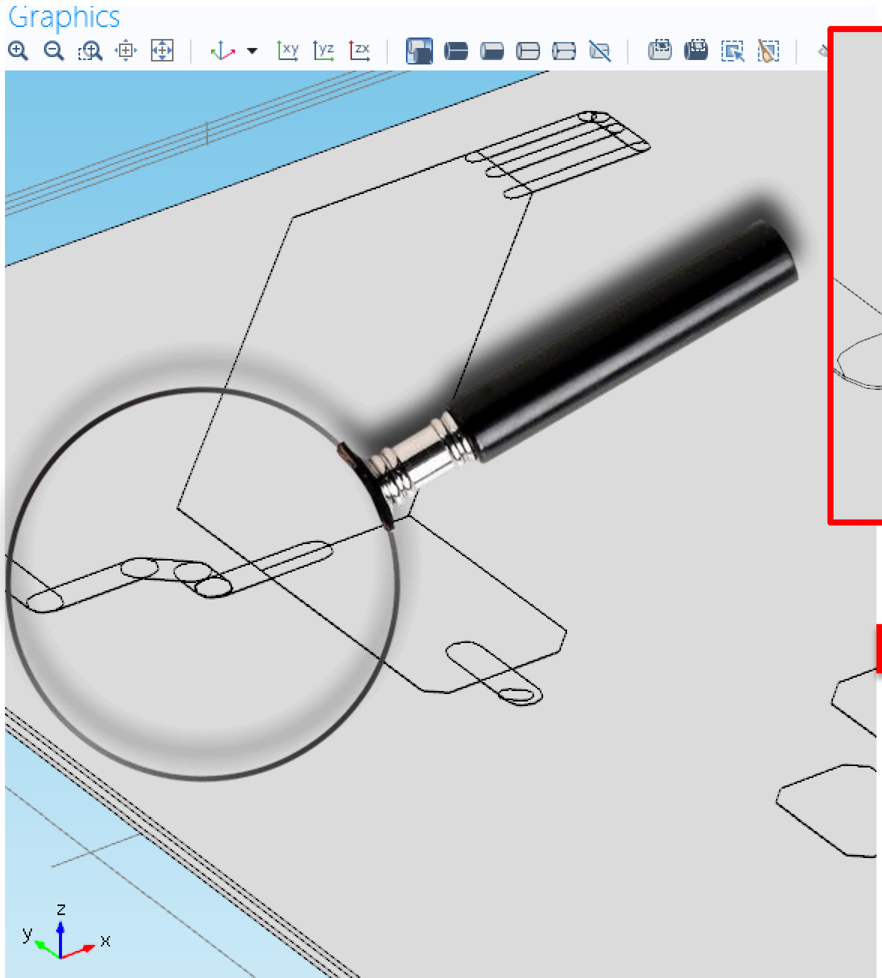
At the industrial partner “**JSC Reshetnev Information Satellite Systems**” request the PCB (ASCII) import was implemented in order to use Altium Designer files.

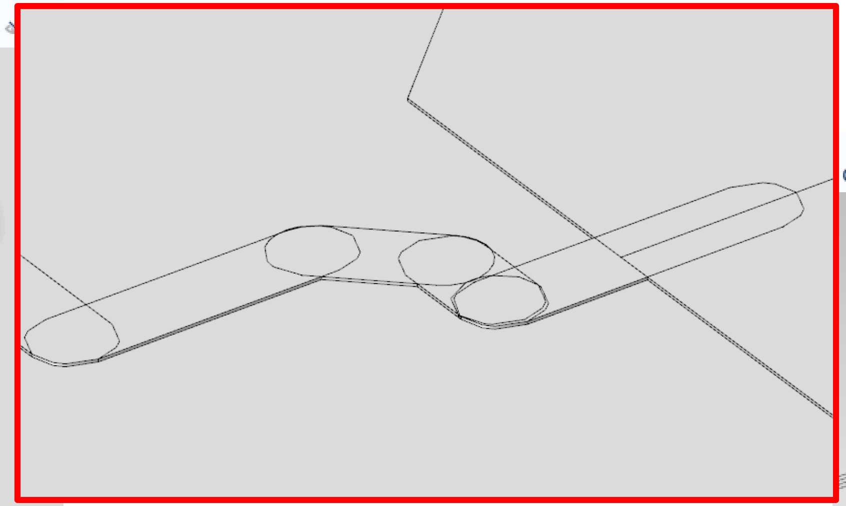
- Geometry improvements

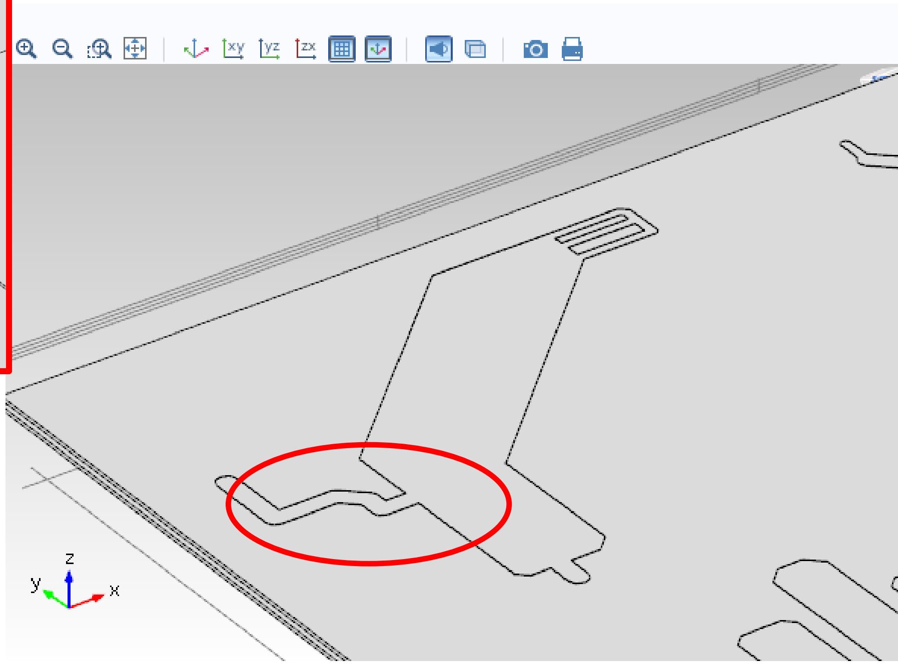
We have designed native three-dimensional kernel to correct inaccuracies obtained during import.

Preprocessing module: Example

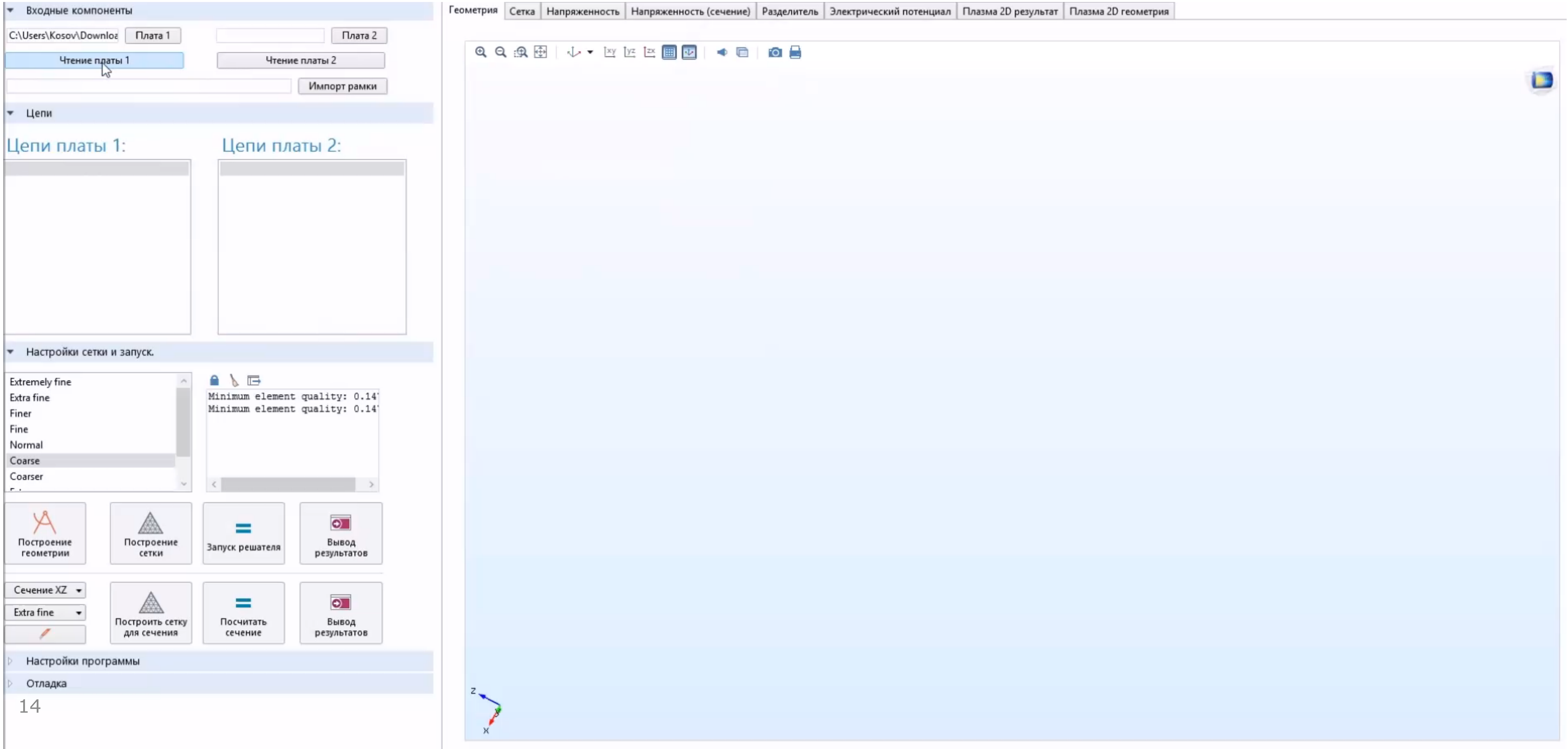
- Automatic removing of inaccuracies in geometrical details.







Live PCB import procedure



Processing module

✓ COMSOL Application Builder
✓ AC/DC Electrostatics + Plasma modules.

- Solve complete electrostatics problem

Find electrostatic potential and electric field absolute value distribution for defined geometry. Border conditions (potentials at conductors) are implied using SPICE simulation results.

- Critical regions location (by estimating of |E| local maxima).

- Compile 2D models of critical regions from 3D using three coordinate sections

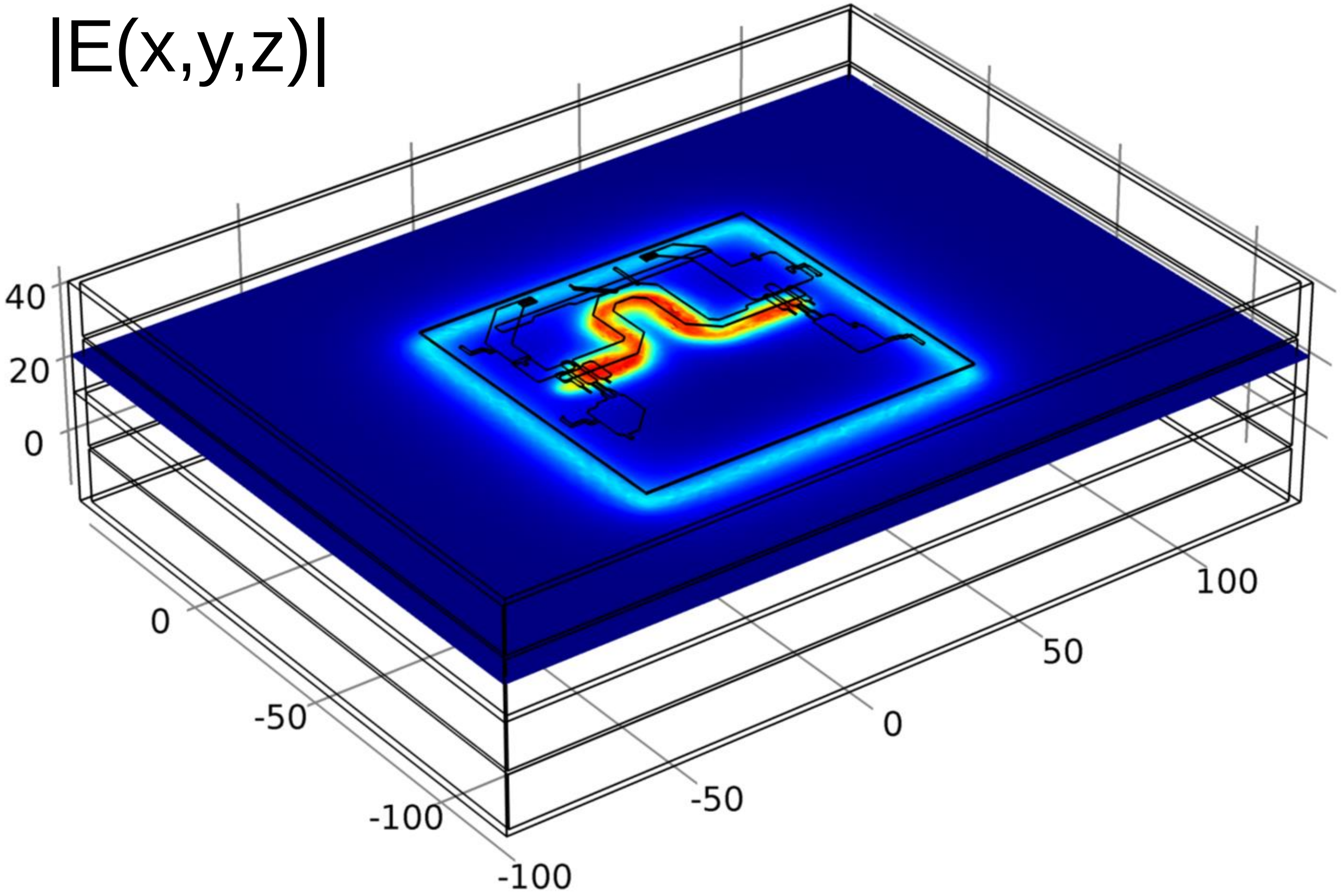
- DC-discharge simulation in 2D models with Parametric Sweep

(in order to obtain critical parameters diagrams)

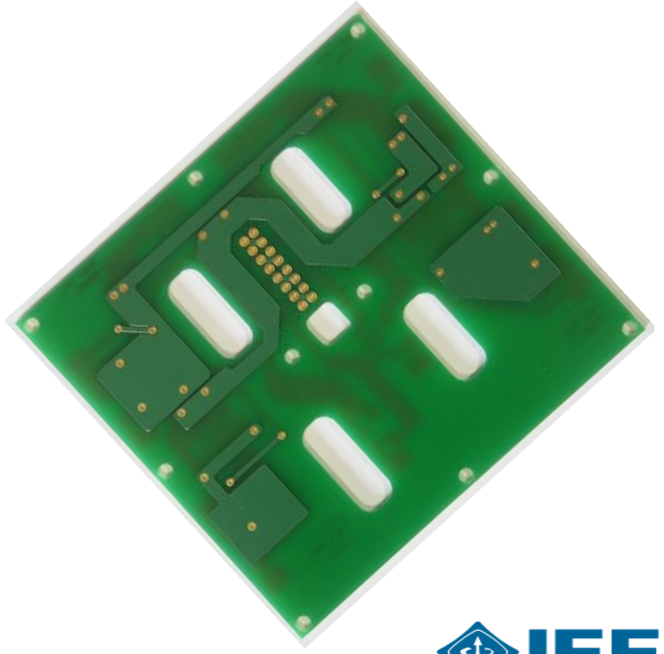
Electric field distribution

Full-scale SPICE + Electrostatics simulation (with AC/DC module of COMSOL Multiphysics)

|E(x,y,z)|



Satellite secondary power supply PCB



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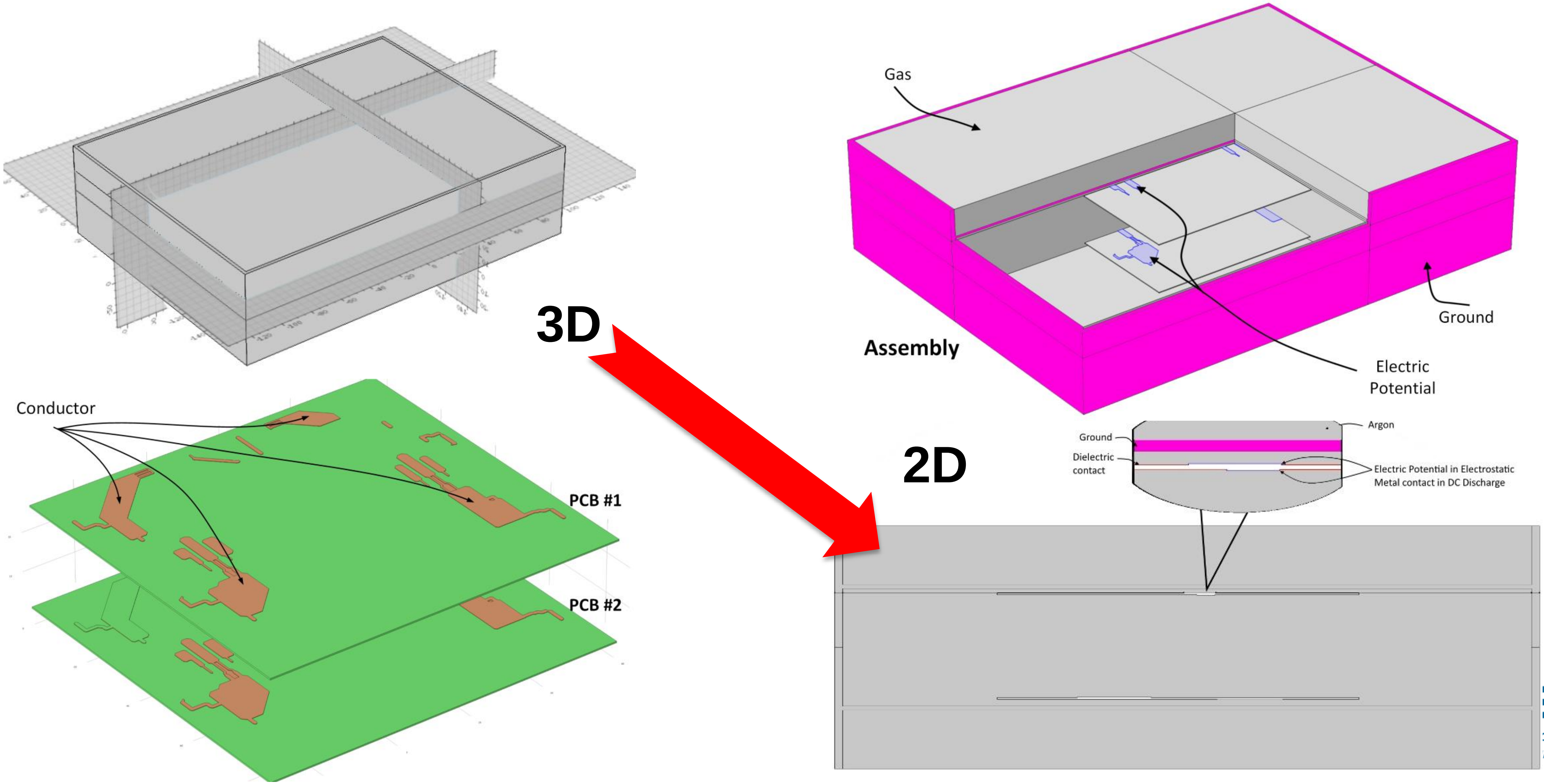
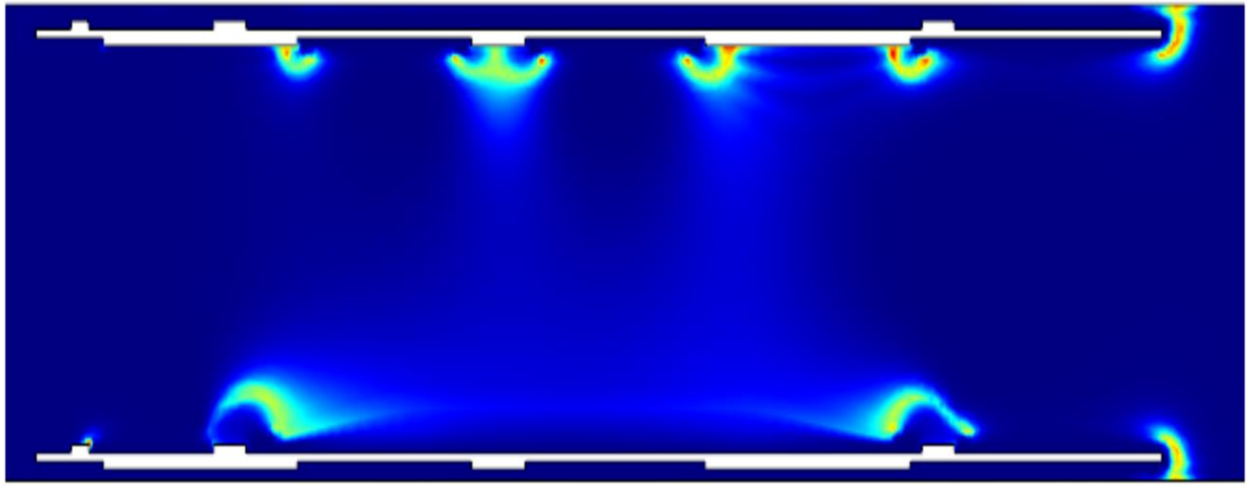
Location of critical regions

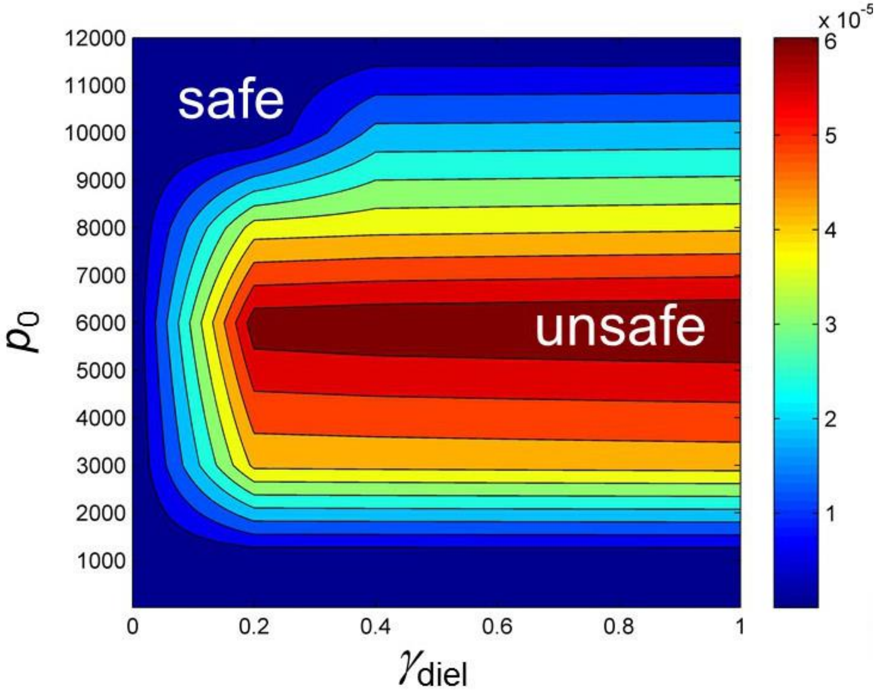


DC-discharge simulation

Computation of critical parameters diagrams using DC-discharge simulation (Plasma module of COMSOL Multiphysics) for each simplified model.



Electron density distribution



Critical parameters diagram

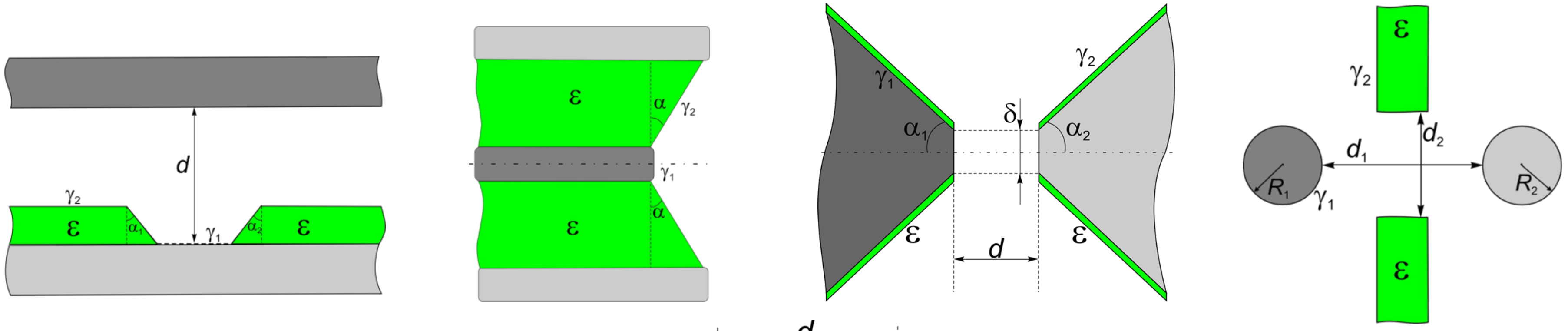
Summary

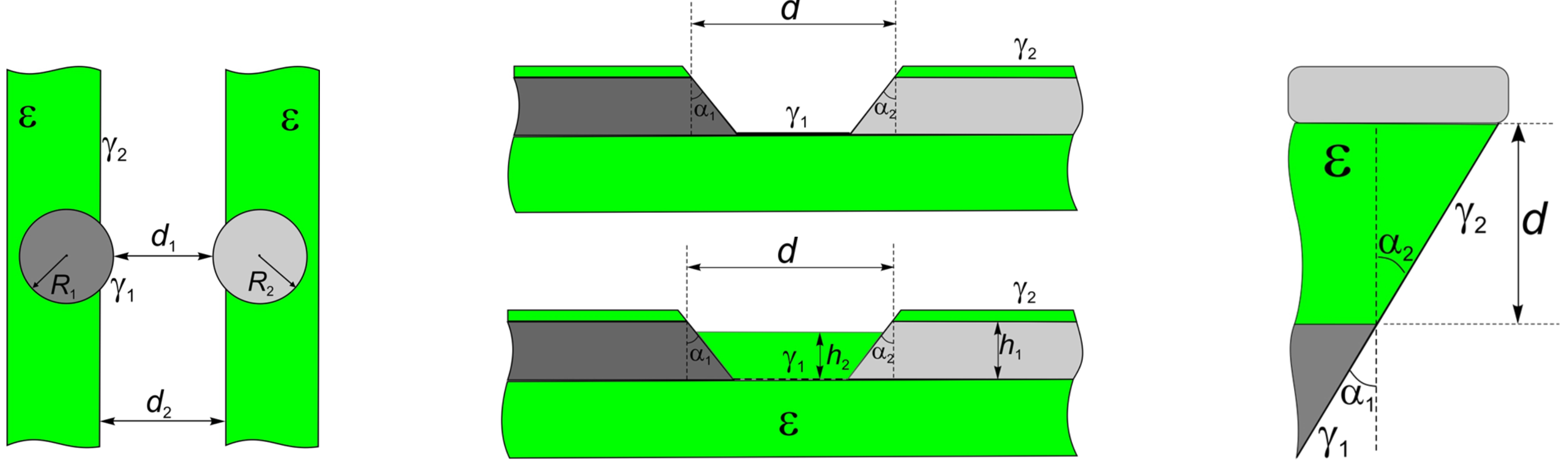
The previously proposed innovative computational approach has been successfully implemented in pilot software system completely built with COMSOL Multiphysics. COMSOL Application builder was used along with COMSOL AC/DC Electrostatics and Plasma modules in order to create a complete simulation cycle.

The developed software enables to combine possible arc positioning with the further investigation of certain regimes of the discharge ignition without full-scale DC-discharge simulation. The software allows upgrading the development technology of arc-resistant electronics intended for operation in the wide range of temperature, pressure and other environment or/and technical parameters.

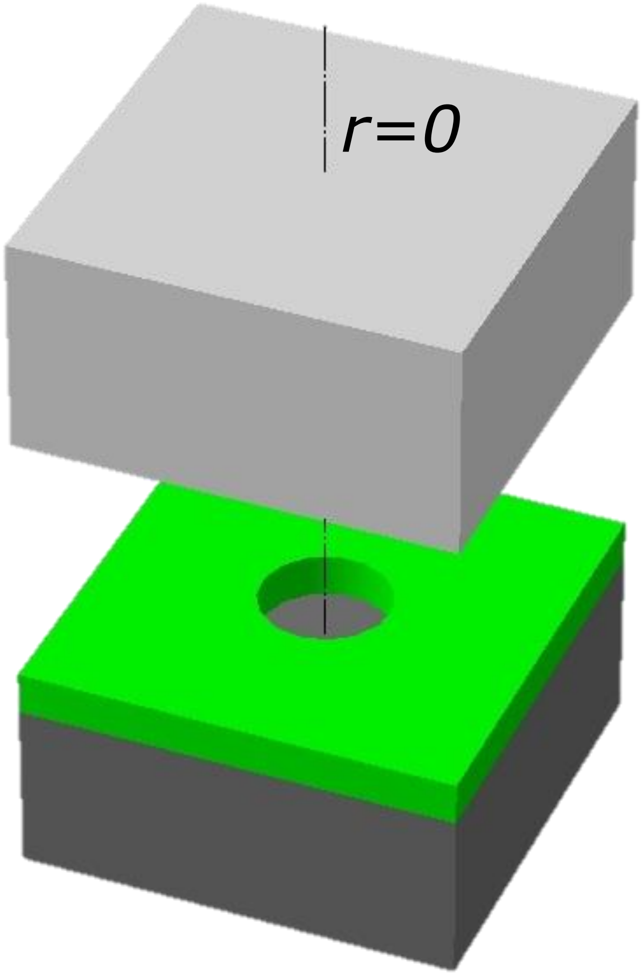
Set of models ("zoo")

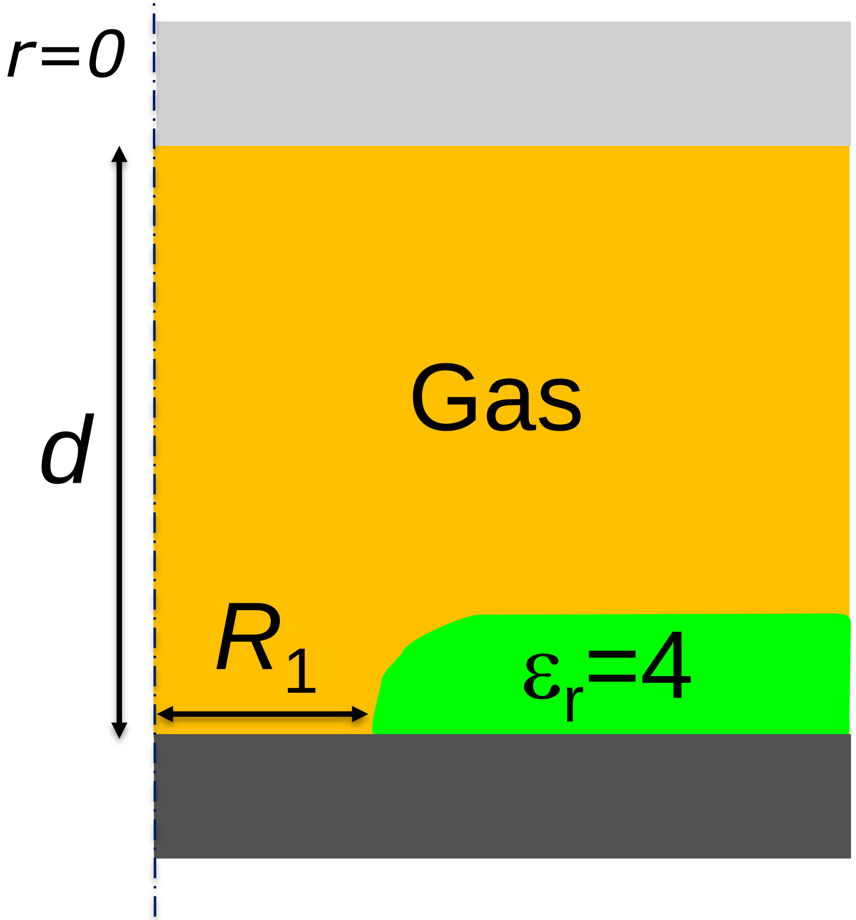
Drawing up of a set of simple two- and three-dimensional geometrical configurations of discharge gaps using preliminary diagnostics results



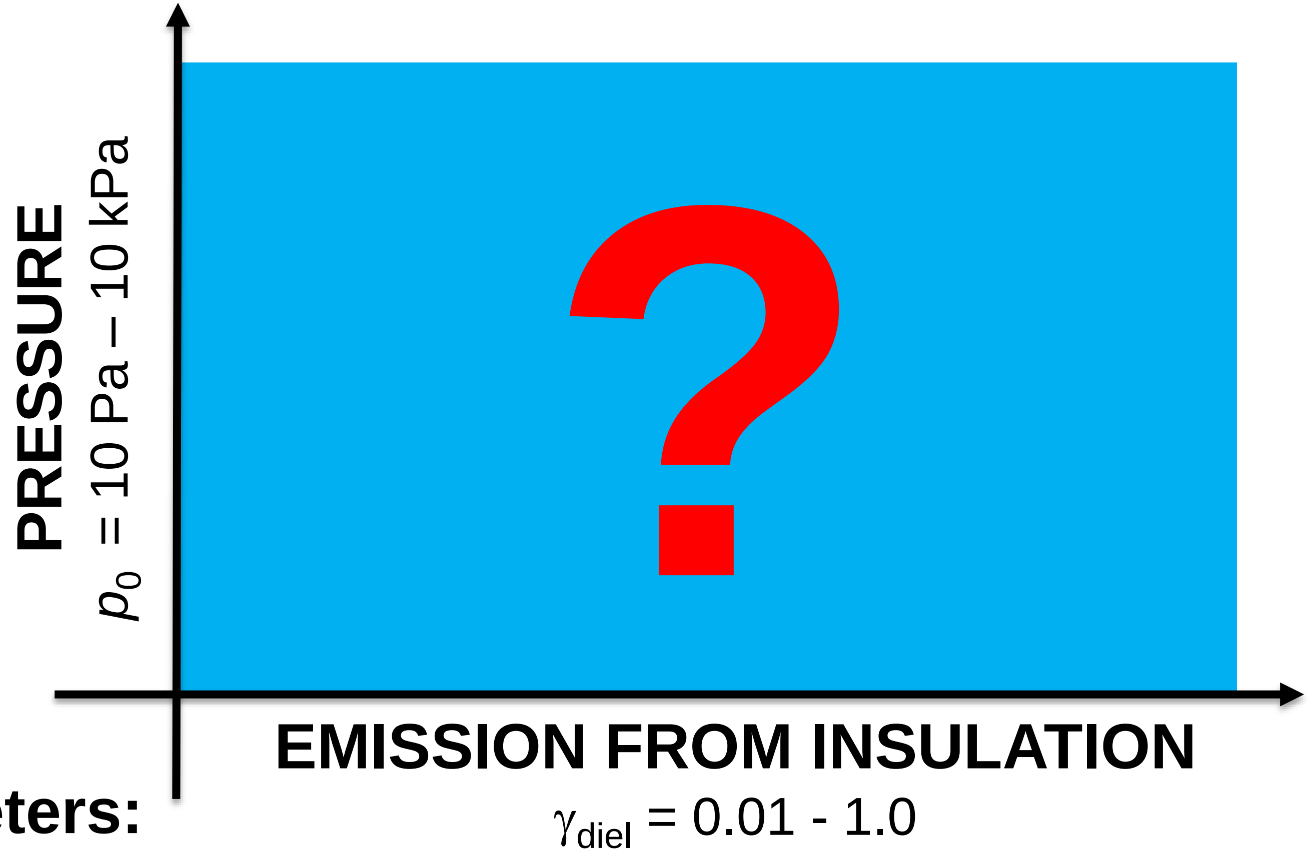


Circular defect in laquer insulating coating (2D-axisymmetric model)





Sample 2D critical parameters diagram (γ_{diel} - p_0 plot)



Other parameters:

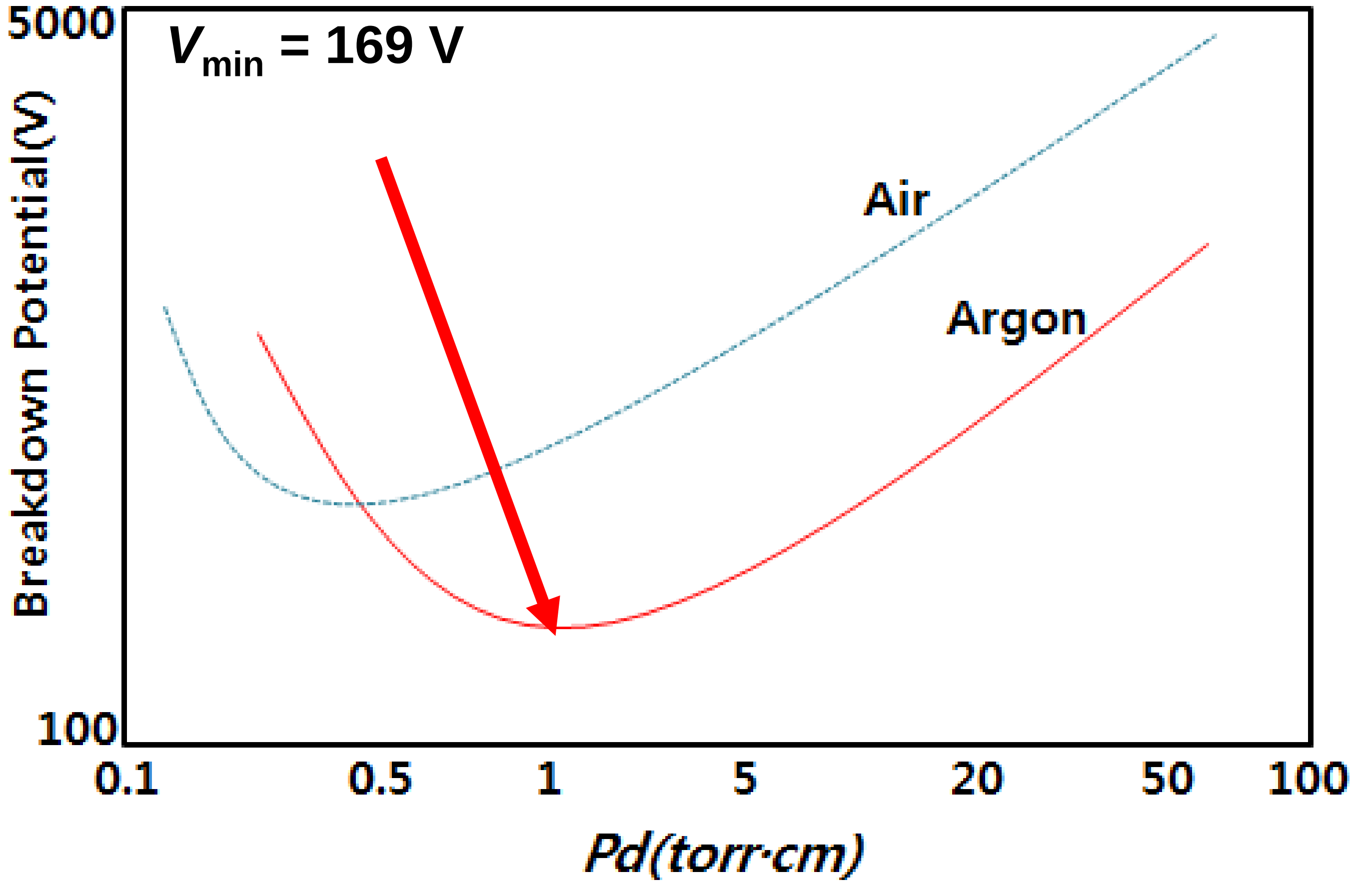
Interelectrode distance – 3 mm

Insulation thickness – 0.05 mm

Initial plasma density – 10^3 cm^{-3}

Applied voltage: two cases

- Reference case V_0 = 200 V (above Paschen's min.)
- Operating case V_0 = 100 V (below minimal breakdown voltage)



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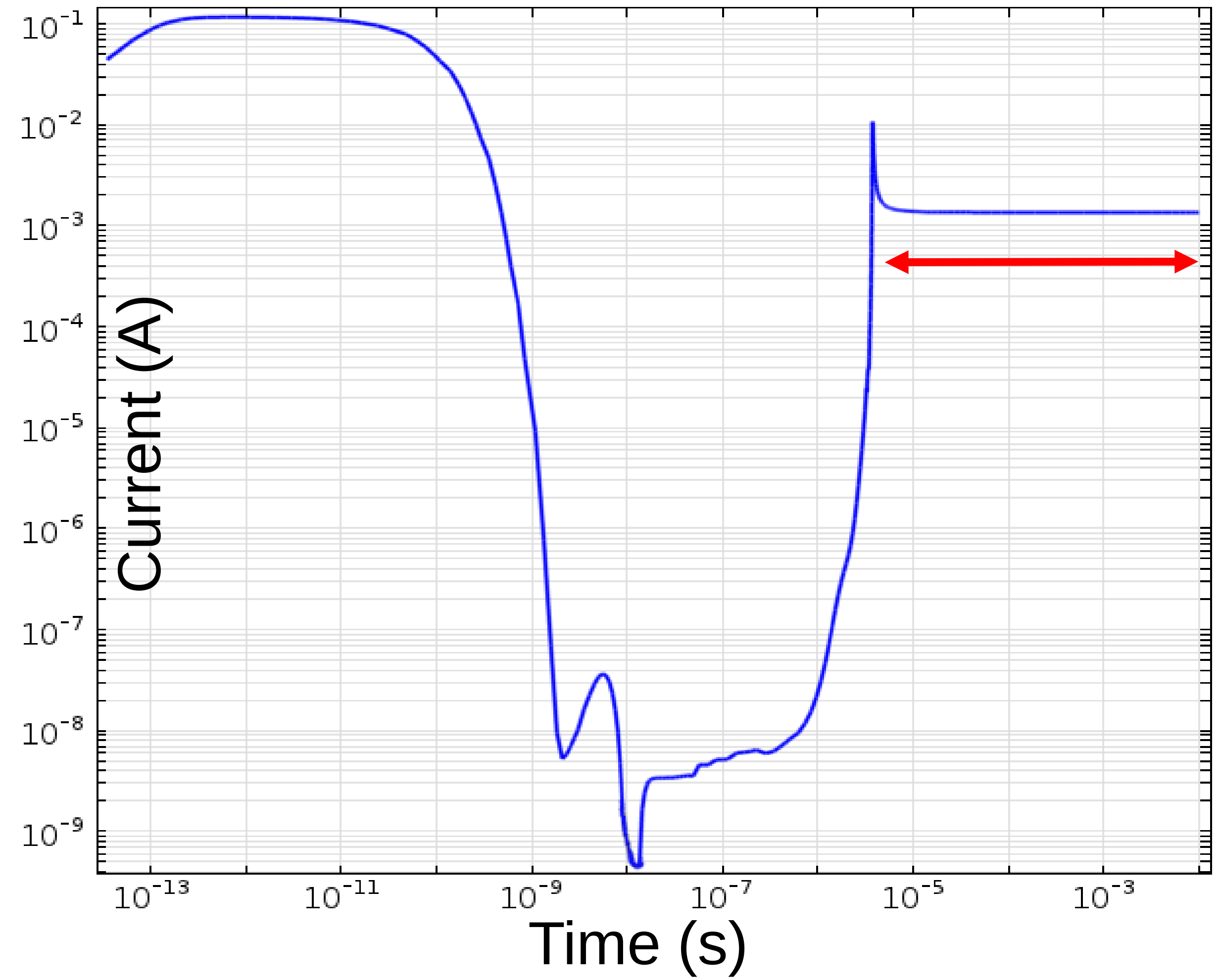
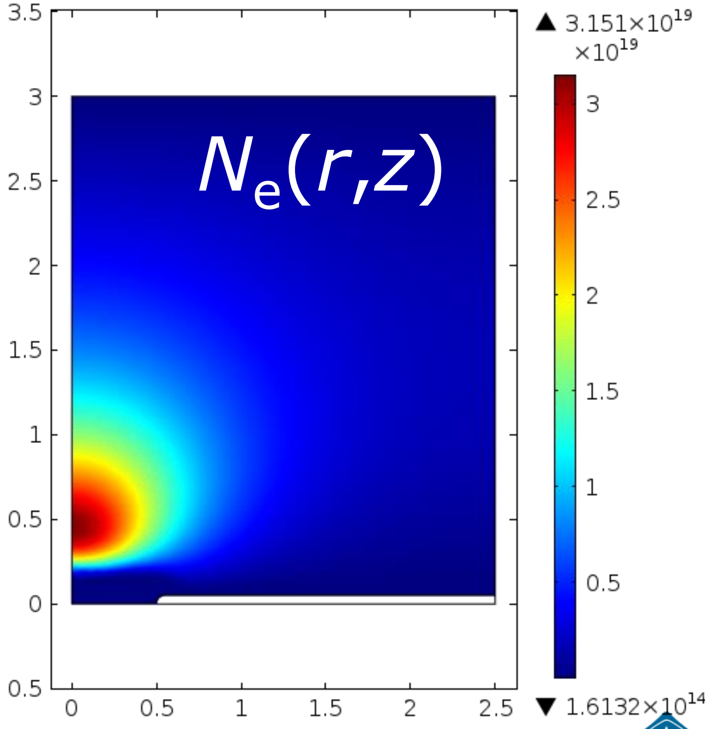
Reference case ($V_0 > V_{min}$): Self-sustained discharge @ 1 ms

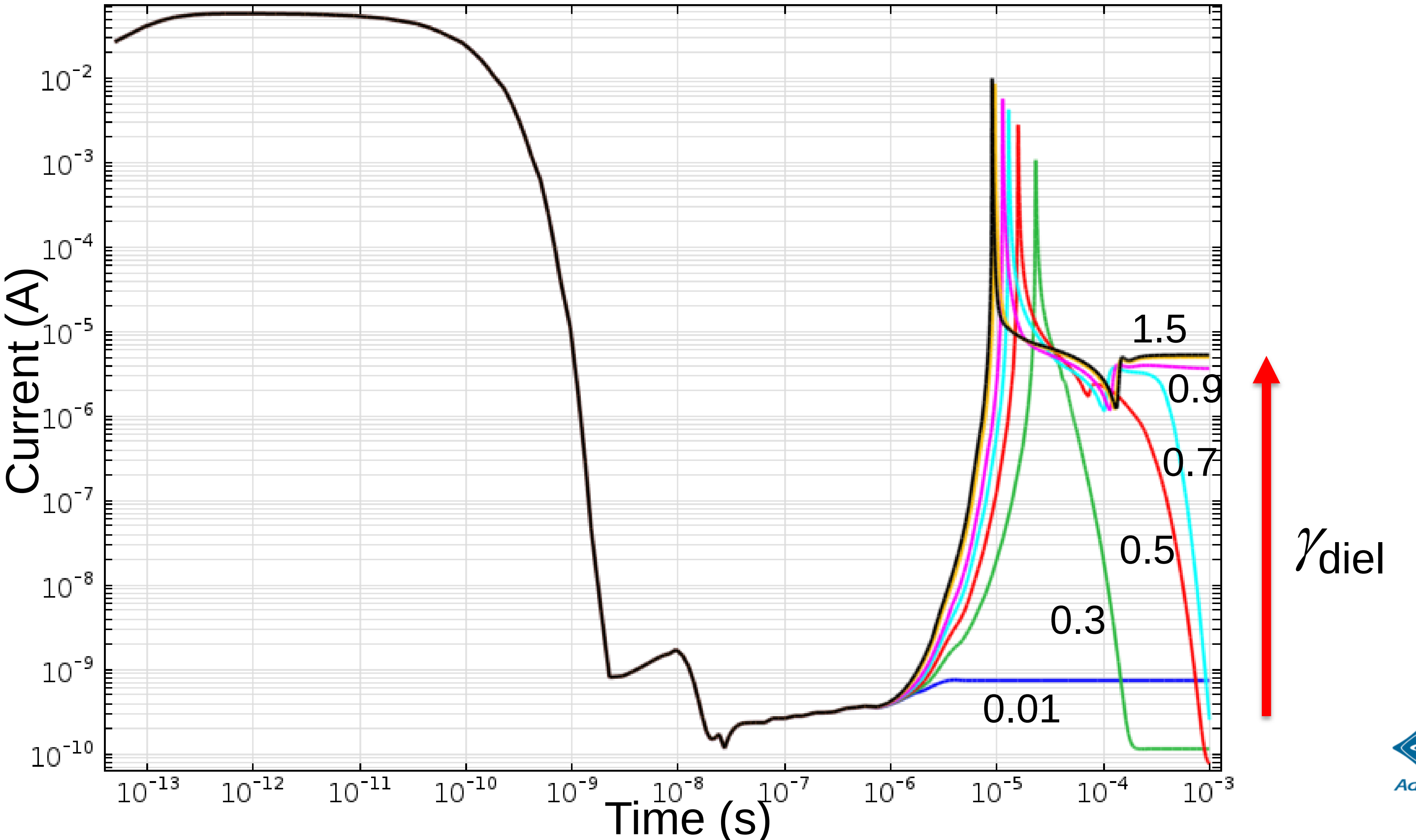
$V_0 = 200$ V, $p_0 = 3$ kPa



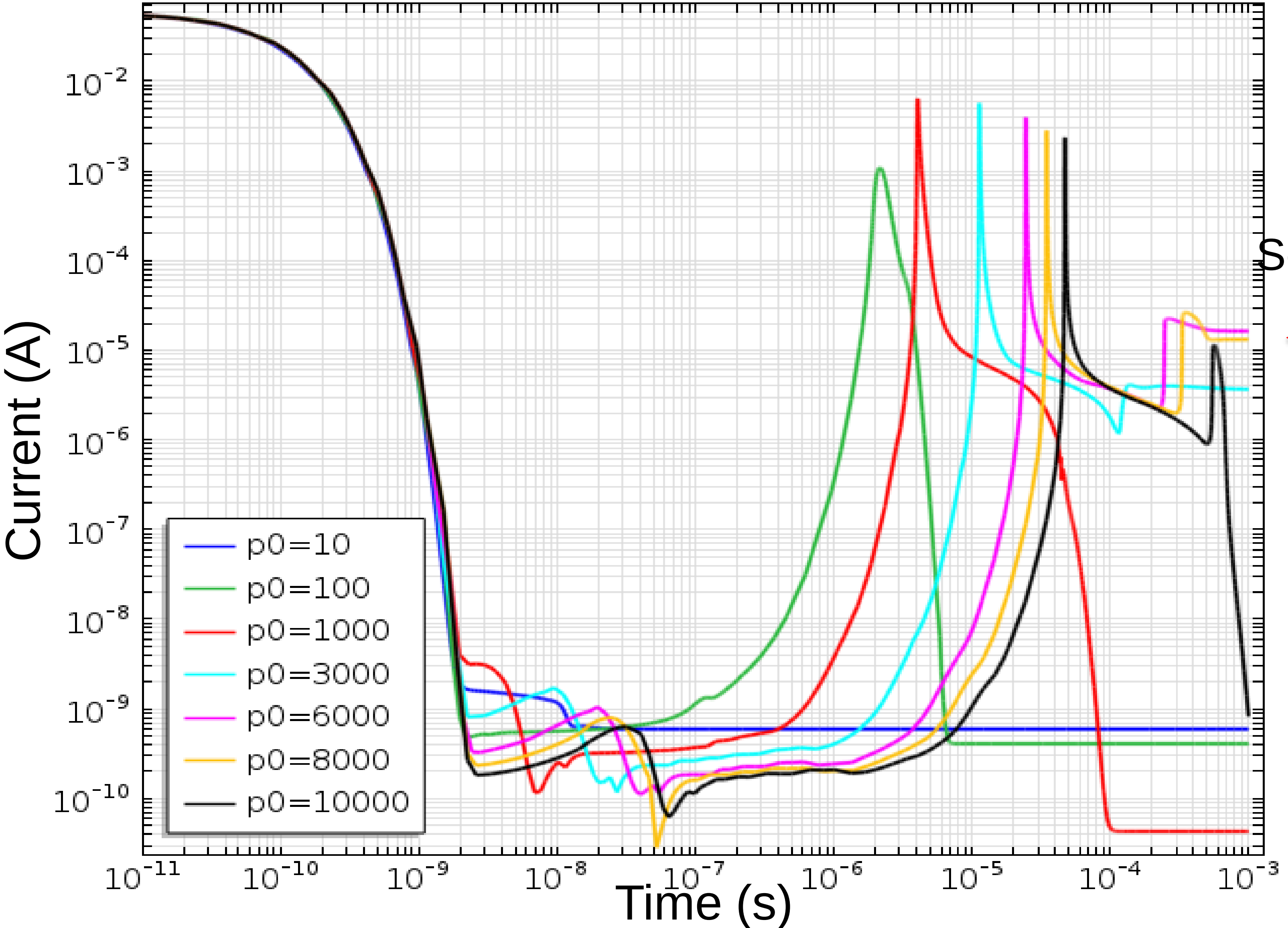
Electrons density



Operating mode
(γ_{diel} variation @ $p_0 = 3\mathrm{kPa}$, $V_0 = 100$ V)



Operating mode
(pressure variation @ $\gamma_{\mathrm{diel}} = 0.9$, $V_0 = 100$ V)



Self-sustained discharge

Critical parameters diagram (γ_{diel}, p_0)